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WELDING PROCESSES

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1. INTRODUCTION.

1.1 Welding is the most widely used method of joining metals. It is used in a great number of the tools and equipment that we use on the job as well as in motor vehicles, ships, and all types of steel structures. In fact, in the manufacture of most appliances used in modern living, some form of welding has been used.

1.2 There are three fundamental divisions into which the welding processes fall. These are:-

- Fusion welding processes in which there is actual melting of the materials to be joined. The heat necessary for fusion is supplied by:-

  (a) chemical means such as combustion of gases, e.g. gas welding; or

  (b) electrical means such as an electric arc.

- Pressure welding processes in which the parts to be joined are heated to a plastic state and pressed together. The heat may be generated by various means including the blacksmiths forge, friction or electrical resistance. The most common processes use electrical resistance as the heat source e.g. spot and butt welding.

- Surface bonding processes do not fall into the welding category but they include valuable techniques that come within the scope of the welder, e.g. brazing. In this process, a thin film of molten filler metal is drawn by capillary action into the narrow space between the sections to be joined.

1.3 This paper describes the most commonly used welding processes under the more practical headings, i.e. gas welding and brazing, arc and resistance welding rather than under the headings listed on para. 1.2.

2. GAS WELDING.

2.1 Gas welding is a general term which is applied to the fusion welding processes where the main source of heat is supplied by the combustion of a fuel gas with oxygen. The gas may be acetylene, hydrogen, liquefied petroleum (L.P.) or coal gas. Acetylene is the fuel gas most commonly used and the term "gas welding" is quite often used when referring to the oxy-acetylene process. Also included under this heading is "braze welding", or bronze welding, as it is often called.

2.2 **OXY-ACETYLENE FUSION WELDING.** In this process acetylene and oxygen are fed to a torch where they are mixed and burned in a high temperature flame. The flame is used to melt both the metal to be welded and a filler rod, which mix to form a molten pool. When the pool solidifies, a strong joint is formed between the two pieces of metal. Fig. 1 shows a "vee-butt" joint formed by this process. This is the joint normally used when joining two pieces of metal plate.

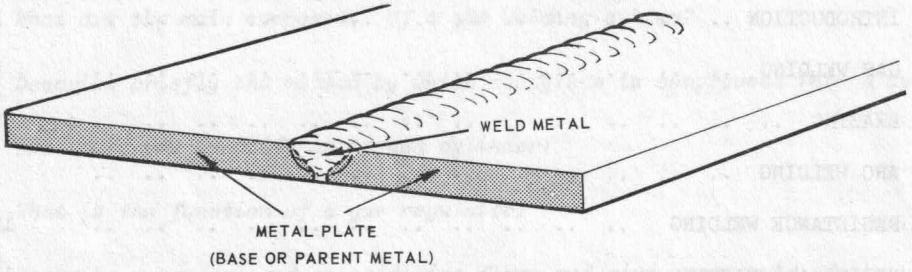

FIG. 1. OXY-ACETYLENE FUSION WELD.

The principle components in an oxy-acetylene welding system (Fig. 2) are:-

- a cylinder of acetylene fitted with a gas regulator;
- a cylinder of oxygen fitted with an oxygen regulator;
- connecting tubing;
- a blowpipe (torch); and
- a range of "tips".

Acetylene is a highly inflammable colourless gas, which has a characteristic odour. When mixed with oxygen it produces the highest known flame temperature of any two gases.

Acetylene in its free state cannot be compressed safely above about 100 kPa. Therefore, to provide for transport of this gas in large quantities, it is necessary to use a cylinder filled with a porous mass, which is saturated with liquid acetone into which the acetylene is dissolved. Under these conditions acetylene at a high pressure may be handled safely. Cylinders are filled to a pressure of approximately 1550 kPa. Acetylene cylinders are painted maroon and are available in various capacities, e.g. 1.8 m^3 and 7 m^3.

Oxygen is an odourless, colourless gas, is non-inflammable but has the property of vigorously supporting and accelerating combustion, hence its value to the welding industry. It is compressed to a pressure of approximately 13 000 kPa into steel cylinders (black). The oxygen cylinder is lighter than the acetylene cylinder as it does not contain any porous material. The capacity of oxygen cylinders in common use is 7 m^3.

Regulators are fitted to the cylinders to control the delivery of oxygen and acetylene at chosen pressures regardless of changes in the cylinder or tubing pressures.

The blowpipe is a mixing device for supplying a combustible mixture of gases to the nozzle. Different types of blowpipes are available to suit various welding techniques.

The blowpipe has valves for oxygen and acetylene which are used to control the flame by varying the amounts of oxygen and acetylene to the mixing chamber.

TIPS AND ACCESSORIES. A range of welding tips or nozzles is available for use with the welding blowpipe. The size tip used will vary according to the metal thickness being welded and the gas pressures used.

An attachment which enables oxy-cutting to be carried out may be used with the welding blowpipe. For heavier cutting and special applications a cutting blowpipe is used.

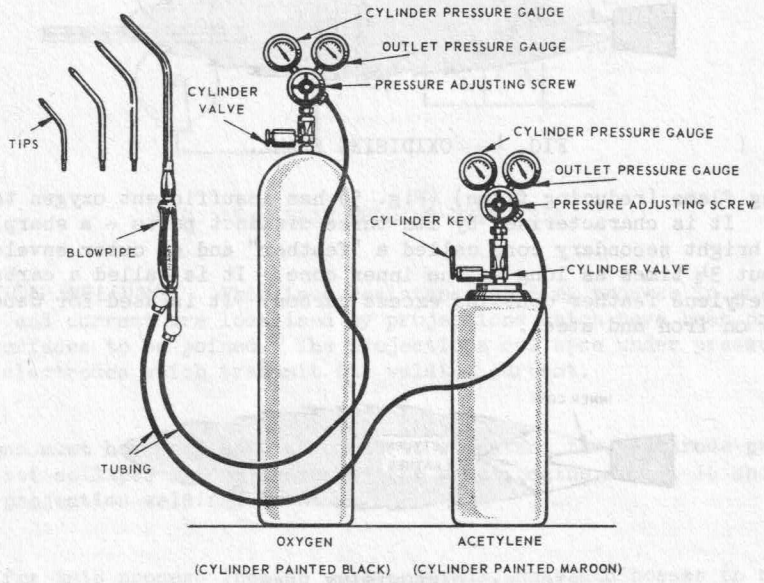

FIG. 2. OXY-ACETYLENE EQUIPMENT.

TYPES OF FLAME. There are three main types of flame used in welding processes. They are:-

- the neutral flame;
- the oxidising flame; and
- the carburising flame.

The neutral flame (Fig. 3) is produced when equal quantities of oxygen and acetylene are supplied to the blowpipe. In this flame, the inner cone, or that portion of the flame used, is sharply defined.

This flame is used for welding the majority of metals, the main one being mild steel. Other materials that require a neutral flame include stainless steel, cast iron, and magnesium alloys.

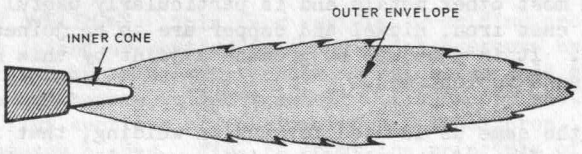

FIG. 3. NEUTRAL FLAME.

The oxidising flame (Fig. 4) contains oxygen in excess of the amount required to burn the acetylene completely. In this flame, the inner cone is shorter than in the neutral flame. The excess of oxygen tends to oxidise the metal. This flame is used when braze welding brass, bronze, manganese, copper etc.

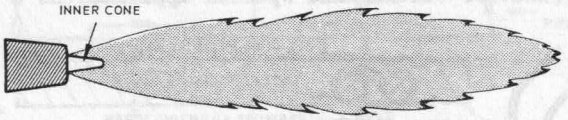

FIG. 4. OXIDISING FLAME.

The carburising flame (reducing flame) (Fig. 5) has insufficient oxygen to burn all the acetylene. It is characterised by its three distinct parts - a sharply defined inner cone, a bright secondary cone called a "feather" and an outer envelope. The feather is about 3½ times as long as the inner cone. It is called a carburising flame because the acetylene feather contains excess carbon. It is used for depositing "hard facing" alloys on iron and steel.

FIG. 5. CARBURISING FLAME.

FLUXES. When welding mild steel, wrought iron and carbon steel, fluxes are not used, but with such metals as cast iron, stainless steel, copper and its alloys, fluxes are used to prevent oxidation. Where flux is used it is usually applied by dipping the heated filler rod into the flux and applying it to the work. In some cases the flux is mixed to a paste and applied to the work and the filler rod.

FILLER RODS. These are used to provide additional metal for the weld. They are available for all metals and are of similar metal to the metal to be welded.

2.3 BRAZE WELDING (BRONZE WELDING). This is a commonly used process for the repair of iron castings. The joint obtained is not a true fusion weld because the metal being joined is not heated to its melting point, but only to a dull red heat. Braze welding relies on the principle that a strong bond can be made between molten brass and clean cast iron or steel at temperatures of about 900°C. The common filler metal was originally brass but many stronger alloys are now available as filler rods. The commonly used grade is a manganese bronze. Heat is supplied by an oxidising flame and a flux is always used. Apart from the repair of castings, braze welding may be used when joining most other metals and is particularly useful when high melting-point metals such as cast iron, nickel and copper are to be joined to alloys with lower melting points. It is possible to produce a joint by this method which is as strong and reliable as a fusion weld.

The joint design is the same as is used for fusion welding, that is, a vee-butt joint made by bevelling the edges of the plate, or if a crack in a casting is to be braze welded, the crack would be enlarged to a vee which is filled to the original level of the base metal.

3. BRAZING.

3.1 Brazing is a process of joining metals in which molten filler metal is drawn by capillary action into the space between closely adjacent surfaces of the parts to be joined. In general, the melting point of the filler metal is above 500°C.

Brazing is not a fusion process as the metal to be joined is not melted. It comes under the category of "surface bonding" techniques and is more comparable to soldering than welding in that only a thin film of the filler metal is required to join the parts or components. Fig. 6 shows typical joints which would be brazed.

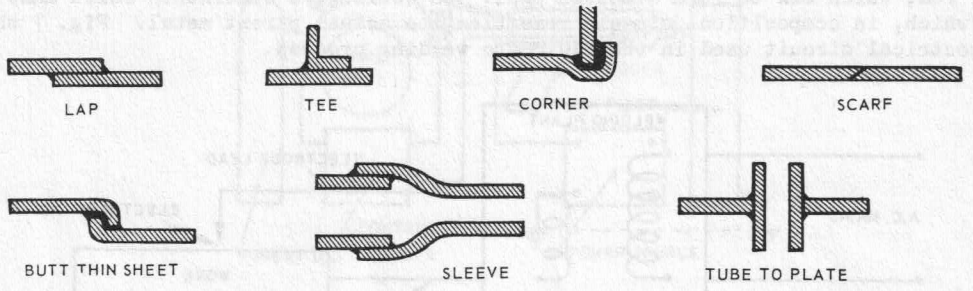

FIG. 6. TYPICAL BRAZED JOINTS.

3.2 The heat for this process is usually supplied by an oxy-acetylene flame. As this flame is very hot, the outer envelope only is used.

3.3 Fluxes for brazing are mixed to a paste and applied to the joint surfaces and the filler rod with a brush. The surfaces must be thoroughly cleaned for good results.

3.4 FILLER RODS. These are referred to as brazing rods or brazing alloys and are available in a range of non-ferrous metals and alloys to suit the metals to be brazed. They include copper alloys, nickel alloys, etc., and must conform to the requirements for particular jobs. They are made in a variety of forms such as wire, foil, sheet, strip and special shapes.

3.5 The parts to be joined are heated until the flux is molten along the joint; the brazing (filler) metal is then added and heating continued just long enough to flow the alloy between the parts to be joined.

3.6 Brazing is used mainly on small joints, tubes, sleeves and flanges in most metals and alloys. Where the method of heating by the oxy-acetylene torch is not suitable for the particular job other sources of heat are used.

Electric current is used in some brazing processes while in others the heat is supplied by a furnace.

In the process called "dip brazing" the parts to be joined are dipped in a bath of molten flux. Steel or malleable iron components are often brazed by this method.

4. ARC WELDING.

4.1 Metal arc welding first came into general use during the First World War and developed gradually during the inter-war years. The Second World War saw widespread use of the process in many fields, including shipbuilding and large structural projects.

The process is now the most widely used method of welding throughout industry, its place being taken only by more specialised techniques.

As this is a fusion process, high temperatures are required to melt the metal to be welded and the electrode, which is in some cases the filler rod.

The heat is developed by an arc, which is struck and maintained across a small gap between the electrode and the metal being welded. The arc, and consequently the heat, is due to the resistance of the air gap to the flow of current, which is converted from electrical to heat energy. The heat of the arc melts the parent metal and the filler rod, which mix to form a molten pool. On cooling, a continuous solid mass forms which, in composition, closely resembles the actual parent metal. Fig. 7 shows the electrical circuit used in the basic arc welding process.

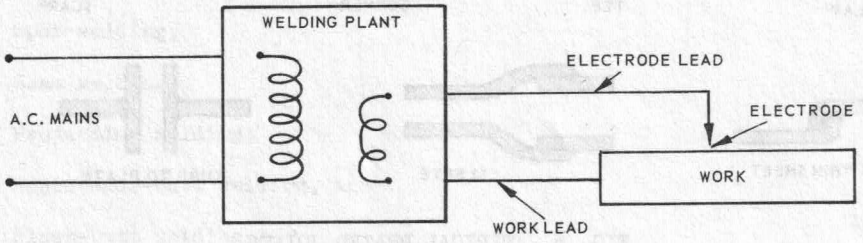

FIG. 7. BASIC ARC WELDING CIRCUIT.

Arc welding processes include:-

- Manual metal-arc welding.
- Automatic arc welding.
  (a) visible arc.
  (b) submerged arc.
- Electro-slag welding.
- Inert gas-shielded arc welding processes.
  (a) Gas tungsten or Tungsten-inert gas (T.I.G.)
  (b) Gas metal arc or Metal inert gas (M.I.G.)
- Atomic hydrogen welding.

Other processes such as electron beam, laser and electrogas techniques are not described in this paper as their use is highly specialised.

4.2 MANUAL METAL-ARC WELDING. This is the most basic form of arc welding in which an electric arc is struck between the metal to be welded and a consumable filler rod called the electrode. The electrode is a metallic wire (the actual metal type depends on the metal to be welded) and an outer coating of flux. The electrode conducts the current and supplies filler material. As the electrode is consumed the coating melts to form a slag which protects the molten pool. The coating facilitates easy striking and stability of the arc and prevents oxidation. The coating also acts as a medium for transfer of useful elements to the molten pool and provides a protective gas around the arc. Bare metal electrodes do not give good results as oxidation and dissolving of nitrogen from the atmosphere will occur. The joint preparation is much the same as for gas fusion welding e.g. a vee type joint is used when welding two pieces of metal plate together.

POWER SOURCES. Coated electrodes are designed for use with various types of power supply. Power supplies are D.C. (direct current) positive or negative, and A.C. (alternating current) at various levels of open circuit voltages.

D.C. may be obtained from a motor generator fed from a three-phase supply or from a generator driven by an engine. Alternatively, D.C. may be produced by the rectification of three-phase A.C. in a selenium plate metal rectifier. D.C. is preferred for the majority of electrodes other than mild steel and is normally connected so that the electrode is positive. This means that the electrons flow from the work to the electrode and produce more heat in the electrode. About two-thirds of the heat generated in the welding arc is concentrated at the positive pole due to the electrons striking it.

One disadvantage of D.C. is "arc blow". Direct welding currents passing through the work produce magnetic fields which can sometimes deflect the arc to such an extent that it behaves as though it is being blown by a jet of air. The effect can be counteracted by coiling the welding cable near the weld in such a manner that the magnetic field due to the coil neutralises that which is causing arc blow. This does not occur with A.C.

A.C. is almost always obtained from either a single-operator or a multi-operator transformer. The welding current from a transformer may be adjusted by one of two methods. One is by means of a hand wheel or handle which varies the magnetic coupling between the primary and secondary windings (leakage reactance). This gives a continuous and smooth variation in current. The other way is by means of a reactor or choke, which consists of a coil wound on a laminated iron core. This coil carries the welding current and may have tappings connected to a selector switch as a means of changing the current, or the iron core may be moved in and out by the operation of a handle or wheel.

Fig. 8 shows a typical power supply (called a welding plant or welding machine) which has provision for connecting the electrode lead to either a high or low current range terminal. The two current ranges are shown on a double scale which corresponds with the terminals.

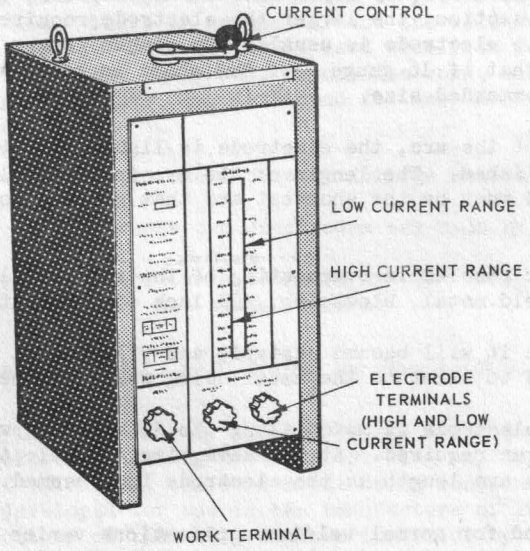

FIG. 8. A TYPICAL WELDING PLANT.

SELECTION OF WELDING CURRENT for a particular job is a most important factor. With too little current, difficulty is experienced in striking and holding an arc, penetration is poor and the shape of the metal deposited on the weld is rounded. Excessive current is accompained by overheating of the electrode and will cause burning through of the meterial and excessive spatter.

Normal current for a particular job may be defined as the maximum which can be used without causing burning, overheating or a rough spattered surface.

Table 1 shows the recommended current range for various electrode sizes.

SIZE OF ELECTRODE		CURRENT RANGE (AMPS)
GAUGE	ACTUAL DIAMETER	
14	2 mm	35 - 55
12	2.5 mm	75 - 100
10	3.15 mm	90 - 135
8	4 mm	130 - 180
6	5 mm	170 - 230

TABLE 1. CURRENT RANGES FOR VARIOUS ELECTRODES.

ELECTRODE TYPES AND SIZES. As a general rule the electrode would be of similar composition to the metals to be welded. For some metals, however, there may be a choice of several electrodes, each of which has particular properties that suit specific classes of work. Often one electrode in the group will be more suitable for general application due to its all round qualities.

The gauge of electrode is generally dependent on the thickness of the metal being welded, the larger the section, the larger the electrode required. For light gauge sheet, the most suitable electrode is usually two gauges larger than the thickness of the work. This means that if 16 gauge (1.6 mm) sheet is being welded, 14 gauge (2 mm) electrodes are the recommended size.

LENGTH OF ARC. To start the arc, the electrode is lightly scratched on the work until the arc is established. The length of the arc is of vital importance to the quality of the weld and must be the shortest arc that gives a good surface to the weld.

An excessively long arc results in overheating of the weld metal, atmospheric contamination of the weld metal, blowholes, and lack of penetration.

If the arc is too short it will become unstable and will result in poor penetration. The electrode will tend to stick to the metal being welded if held too close.

SPEED OF TRAVEL. The electrode is moved along the joint being welded at a speed that will give the size of run required. At the same time, the electrode is fed downwards to maintain the correct arc length as the electrode is consumed.

The correct travel speed for normal welding applications varies between approximately 120 mm and 230 mm per minute, depending on electrode type, size, and size of run required. Excessive speed leads to poor fusion, while slow speed causes arc instability, overheated metal, and poor fusion.

4.3 AUTOMATIC ARC WELDING. Early automatic welding processes used a supply of electrodes which had to be replaced manually in the equipment as the weld progressed. This had disadvantages which were overcome by the introduction of a coated electrode in coil form fed automatically to the weld. This is known as the "visible arc process". The dangers associated with the visible arc, and on the other hand the advantages gained by the automatic principle led to the introduction of a process called "submerged arc" welding which uses a coiled bar wire electrode automatically fed through feed rollers. The flux is supplied separately as a free flowing powder from a hopper and is deposited on the joint ahead of the electrode wire. The arc is completely blanketed, and hidden from view. For this reason a guide pointer is fitted which enables the operator to make adjustments to keep the arc in the required path. Fig. 9 shows this system in simple diagrammatic form.

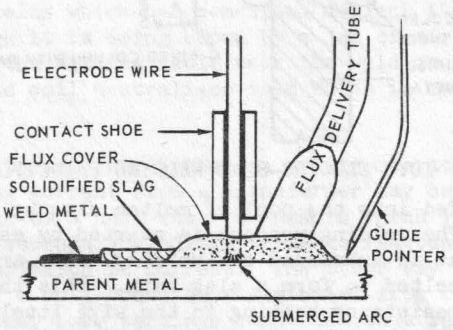

FIG. 9. THE SUBMERGED ARC PRINCIPLE.

The heat of the arc melts the wire, some of the material being welded, and a proportion of the flux. The melted flux flows to the surface of the weld and solidifies. Advantages of this method are that the arc is quiet and there is no annoyance from fumes or glare, also the weld metal is protected from the atmosphere, thus eliminating oxidation. There is no spatter and the weld surface is very smooth, being almost devoid of ripple. This method is used widely in fabrication of steel work, building up parts of large equipment, repetition work, etc. Various modifications of this process have been developed for use in heavy fabrication industries and these include:-

- tandem-arc welding where one electrode follows another;
- parallel-arc welding where two electrodes are side by side; and
- series-arc welding where two electrodes are set at an angle to each other and converge just above the plate surface.

The power supply may be either A.C. or D.C. and as high as 2000 amperes.

ELECTRO-SLAG WELDING. This process may be regarded as a development of the submerged arc process, the main difference being that electro-slag welding is a single run process irrespective of thickness, the weld metal being contained by water-cooled copper shoes. It was developed for use in the manufacture of large castings and is widely used in many sections of the heavy engineering industry.

Fig. 10 shows the basic principle of this process.

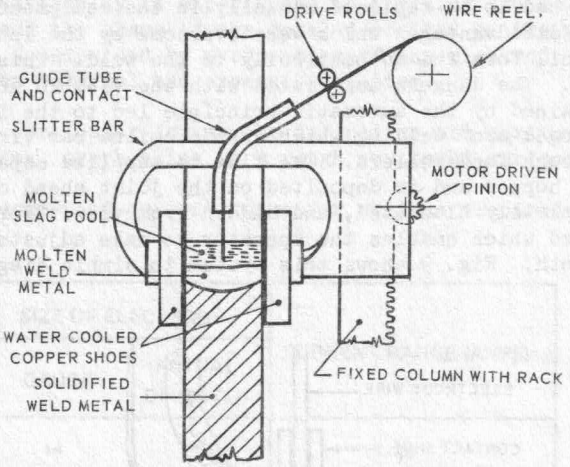

FIG. 10. ELECTRO-SLAG WELDING PRINCIPLE.

Electrode filler wire is fed into the pool of molten slag by the drive rolls and through the guide tube. The welding process is started by establishing an arc under a layer of powdered flux as in submerged arc welding. The arc persists until sufficient flux has been melted to form a slag bath. This then extinguishes the arc and melting continues by resistance heating in the wire itself before it melts, and further heat is developed by the current passing through the molten slag.

4.5 INERT GAS-SHIELDED ARC WELDING PROCESSES. The two main types of process which fall under this heading have become known as TIG welding and MIG welding. These letters stand for "tungsten inert gas" and "metal inert gas" respectively. In these processes argon or helium gas is used as a shield for the arc and weld puddle, thus oxidation is prevented.

In the TIG method (sometimes called argon-arc welding) the heat is produced by an electric arc maintained between a non-consumable tungsten electrode and the metal to be welded. The electrode acts as a conductor only, filler metal being added separately if required. The heated weld zone, the molten metal and the electrode arc are shielded from the atmosphere by a blanket of the inert gas. A weld is made by applying the arc heat so that the abutting edges of the work are melted and joined together as the weld metal solidifies. This process can be applied manually or automatically. It is used for welding most grades of carbon alloy and stainless steels, aluminium, magnesium, copper and their alloys and some hard surfacing alloys. This method has the advantage that damaging flux residues are not formed on the metal being welded. Fig. 11 shows the "torch" used in the TIG process.

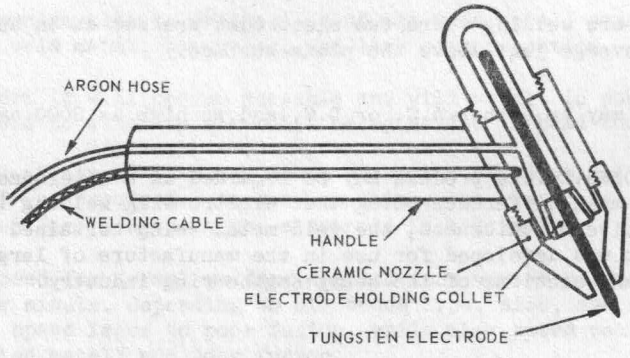

FIG. 11. TORCH USED FOR TIG WELDING.

The MIG process differs from the TIG process in that a consumable electrode is used instead of the non-consumable tungsten electrode. The consumable electrode is usually in the form of a coiled, uncoated wire and is fed by a motor drive to the argon-shrouded arc. (Fig. 12).

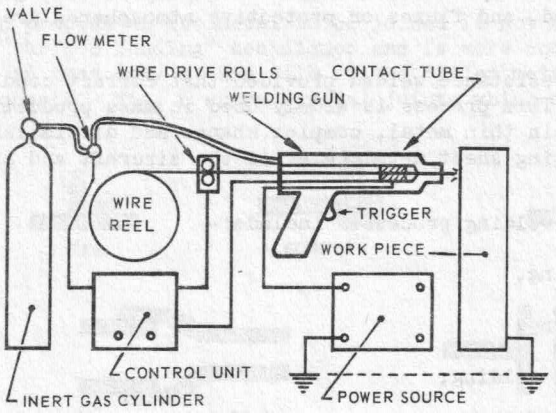

FIG. 12. MIG WELDING PRINCIPLE.

Most MIG welding equipment is used in semi-automatic applications where the operator holds the torch or gun through which the wire, gas, welding current and sometimes a cooling medium (water or air) are fed.

This process, which was first developed for welding aluminium and its alloys is now used for a similar range of metals as are welded by the TIG process.

When steel is to be welded by this process the gas used is CO2 (carbon dioxide) gas. The term "CO2 welding" is often used in this case but it is actually a branch of MIG welding.

4.6 ATOMIC HYDROGEN WELDING. The arc is struck in this method between two tungsten electrodes in a stream of hydrogen. The hydrogen atoms are ionized and then recombine on the metal surface, giving up heat which causes fusion (3750 °C at the flame tip). The hydrogen also burns but this is not the main source of heat. The hydrogen surrounds the melting zone so protecting the molten metal from oxidation. The process is expensive but is valuable in joining thin sheet metal and fine wires. It is also used for repair welding of metal tool tips and dies made of alloy steel. Welds are smooth in appearance because the hydrogen keeps the molten pool clean and the arc causes no turbulence in the pool.

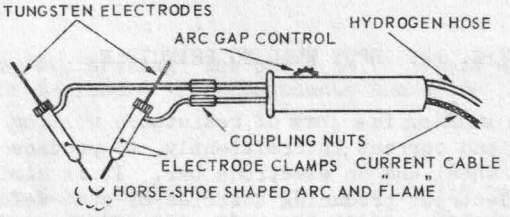

FIG. 13. THE ATOMIC HYDROGEN TORCH.

5. RESISTANCE WELDING.

5.1 Resistance welding is a general term used to describe a group of welding processes in which parts of the components to be welded are heated to a plastic or slightly fused state by an electric current and pressed together. Normally no filler metal is added, and fluxes or protective atmospheres are rarely used.

Most metals can be resistance welded provided that correct conditions of current and time are selected. This process is widely used in mass production manufacturing due to its ability to join thin metal, complex shapes and dissimilar metals. The process is used for fabricating sheet metal, e.g. in the aircraft and automotive industries.

Types of resistance welding processes include:-

- Spot welding,
- Seam welding,
- Projection welding,
- Resistance-butt welding, and
- Flash-butt welding.

5.2 SPOT WELDING. This is the most common form of resistance welding and is a process in which the weld is produced at a spot in the material to be welded. The work is placed between two copper electrodes and pressure is applied to ensure good contact. Heating of the weld area begins where the parts to be joined touch each other, and is due mainly to contact resistance. The parts are heated to a plastic or slightly fused state. The heat generation continues until the current flow is terminated after which the metal cools and solidifies while still under the forging pressure of the electrode. Fig. 14 shows the basic spot welding principle. The principle is used in several slightly different forms e.g. stitch welding, where the successive spot welds overlap, and multiple spot welding in which two or more spot welds are made simultaneously.

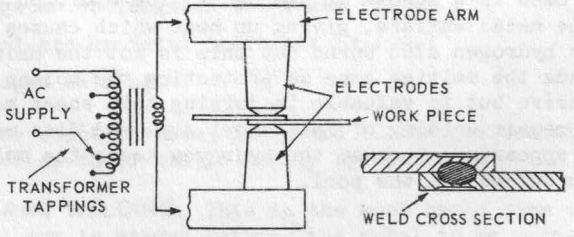

FIG. 14. SPOT WELDING PRINCIPLE.

5.3 SEAM WELDING. Seam welding is a form of resistance welding in which pressure is applied continuously and current intermittently, to produce a linear weld, the work being held between a wheel and an electrode bar. It is similar to spot welding in principle, the wheel electrode producing a series of spot welds which can be made to overlap. Fig. 15 shows the principle of seam welding.

The process is used for producing gas and liquid containers and has the advantage of speed (maximum 3.6 metres per minute)

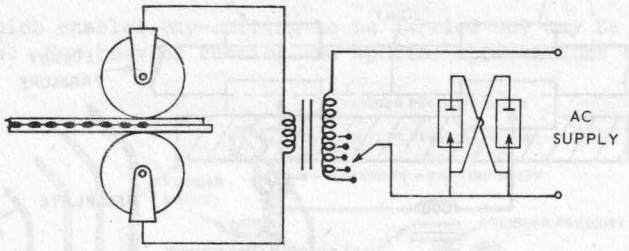

FIG. 15. SEAM WELDING PRINCIPLE.

5.4 PROJECTION WELDING. This is a resistance welding process in which the pressure and current are localised by projections which have been previously made on the surfaces to be joined. The projections collapse under pressure from the copper block electrodes which transmit the welding current.

The projections must have adequate strength to withstand the electrode pressure so that they do not collapse before fusion of the metal begins. Fig. 16 shows the principle of projection welding.

Typical uses for this process include welding studs, nuts and bosses to sheet metal. In this technique the projections may be dome-shaped or conical.

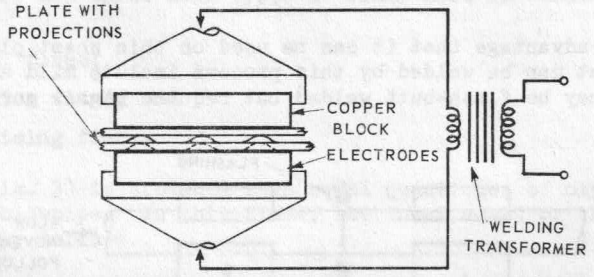

FIG. 16. PROJECTION WELDING PRINCIPLE.

5.5 RESISTANCE-BUTT WELDING. This is a resistance welding process in which the components to be joined are butted together under pressure and current is allowed to flow until a temperature is reached at which the ends of the components reach a plastic state and become welded together. Its use is restricted to the joining of round and flat sections of small cross-sectional area. A typical example is the joining of band-saw blades. Fig. 17 shows the principle of resistance-butt welding and the weld profile.

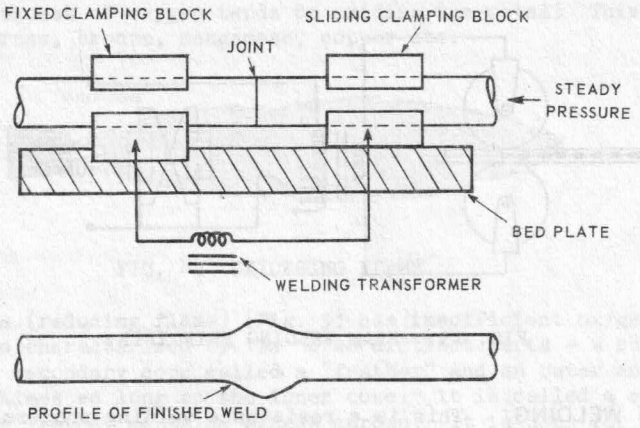

FIG. 17. RESISTANCE-BUTT WELDING PRINCIPLE.

5.6 FLASH-BUTT WELDING. This process differs from resistance-butt welding in that the voltage is applied to the components before their ends are brought together. As soon as they touch a high current flows and flashing occurs. This is sustained by applying only a very light pressure to hold the components together. Flashing is allowed to continue until a welding temperature has been reached; the current is cut off and the components are forged together under a load applied suddenly. The profile of the weld is quite different to that formed by resistance-butt welding process. Fig. 18 shows the flash-butt welding principle and the weld profile.

This method has the advantage that it can be used on thin sheet plate in addition to rods. Materials that can be welded by this process include mild and alloy steels. Non ferrous metals may be flash-butt welded but require higher currents.

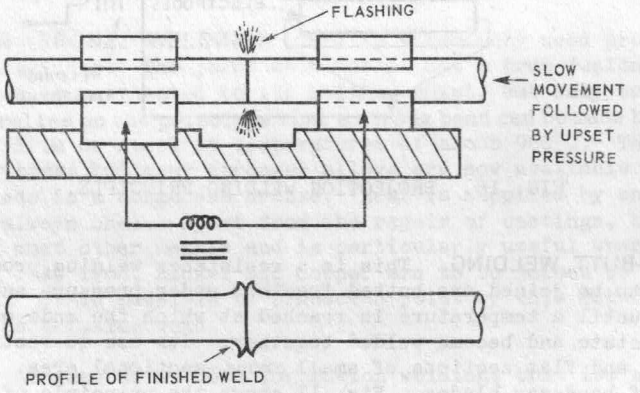

FIG. 18. FLASH-BUTT WELDING PRINCIPLE.

6. HEALTH AND SAFETY.

6.1 Certain dangers associated with welding are obvious, such as electric shock and burns. Other hazards exist which are less obvious, these are:-

- damage to the eyes;
- dermatitis risk;
- fume risk;
- toxic risk;
- asphyxiation risk; and
- noise risk.

6.2 EYE DAMAGE. Damage to the eyes can be caused by either radiation from the electric arc or the spatter of hot particles from the weld. Protective goggles are worn to protect the operator from these hazards. Screens are erected around the work where possible, to protect other workers. Radiation from the electric arc will cause temporary blindness and great care must be taken whenever this process is used.

6.3 DERMATITIS. This can arise from contact with fluxes and similar materials. Solvents also cause dermatitis if handled with bare hands. Gloves will give protection against this hazard.

6.4 FUME RISK. Unpleasant fumes are given off by some types of arc electrodes but these are usually not harmful. Dangerous fumes are more likely to result from coatings on materials being welded.

6.5 TOXIC RISK. Toxic fumes are given off by zinc, cadmium, lead and an element called beryllium which is sometimes used in copper alloys.

Carbon monoxide, a toxic gas, can be formed in the CO2 shielded processes but not normally in harmful amounts.

Oxides of nitrogen, also toxic, can form in the oxy-acetylene process or in electric arcs in high temperatures.

As these and other toxic gases may be present in varying quantities in the welding processes, it is important that adequate ventilation is provided in all work areas. A respirator should be worn when welding any metal that may give off toxic fumes.

6.6 ASPHYXIATION RISK. There is a risk of asphyxiation (suffocation) due to lack of oxygen in certain circumstances as the products of combustion contaminate the air. Here again, the need for adequate ventilation is apparent. As in para. 6.5, a respirator should be worn where necessary.

6.7 NOISE RISK. Certain types of noise can damage the hearing. These are not necessarily banging noises but high pitched screaming or hissing that accompanies some processes. Some flash-butt welding machines for instance, produce noise of this nature. Protection should be provided by ear plugs or muffs.

7. TEST QUESTIONS.

1. *What is meant by the term "fusion welding"?*

2. *How does the "surface bonding" process differ from the fusion process?*

3. *In gas welding, the flame is fed by a mixture of two gases. Name the two gases generally used.*

4. *Sketch the type of joint preparation necessary when butt welding two pieces of 10 mm steel plate.*

5. *What are the main components of a gas welding system?*

6. *Describe briefly the method by which acetylene is compressed into a cylinder.*

7. *How would you identify an oxygen cylinder?*

8. *What is the function of a gas regulator?*

9. *Describe a neutral and an oxidising flame and give an example of the use of each.*

10. *What is the difference between "braze welding" and "brazing"?*

11. *Describe the manual metal-arc welding principle.*

12. *How is flux supplied to the joint in the manual metal arc welding process?*

13. *How is A.C. obtained and regulated for arc welding?*

14. *On what factor does the gauge of electrode depend?*

15. *The rate at which the electrode is moved along the weld is important. What is the effect of excessive speed?*

16. *Give a brief description of the "submerged arc" process.*

17. *What is the reason for using a gas "shield" in some of the welding processes?*

18. *Name three of the "resistance" welding processes, and give an example of the use of each.*

19. *Certain dangers are associated with welding, such as shock or burns. List four other hazards which may be present, but are less obvious.*

20. *What methods of protection are provided to guard the operator against the hazards listed in your answer to Question 19?*

END OF PAPER.

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